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Willberg, Elias

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What do trip data reveal about bike-sharing system users?

Elias Willberg [a,b,*], Maria Salonen [a], Tuuli Toivonen [a,b]

[a] Digital Geography Lab, Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland
[b] Helsinki Institute of Sustainability Science, Institute of Urban and Regional Studies, University of Helsinki, Helsinki, Finland

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ABSTRACT

Bike-sharing systems (BSS) have rapidly been established in many cities worldwide. The benefits that systems potentially provide are increasingly debated with concerns that the BSS may mostly benefit limited groups of citizens. Understanding how, when and by whom these systems are used may help to plan the system to be widely employed and inclusive.

Trip data generated by the BSS are among the more analysed data types in the BSS literature, as they are often readily available for scholarly use. Most often, trip data are used to study the origins and destinations of the trips and their spatial patterns. In this paper, we focus on analysing how well trip data can be used to understand the demographic characteristics and usage profiles of BSS users.

We first analysed the use of BSS trip data in the recent scholarly literature. We then used data from the Helsinki BSS from 2017 (~1.5 million trips) as a case to study the potential of trip data for future BSS studies. The Helsinki BSS, launched in 2016, is considered to have been a success, as it exhibits one of the highest use rates in the world. We aimed to understand how this popular system has served different user groups.

We demonstrate the value of BSS trip data in understanding user characteristics and usage profiles and show that trip data have not yet been fully used for these purposes in the scholarly literature. Even considering its limitations, trip data can provide information that it is important for BSS managers and urban planners when understanding and developing the system inclusiveness. In Helsinki, we show that the BSS use is largely contributed by a limited group of people whose home area and daily travel needs likely align well with the system network. These findings point to challenges in system inclusiveness despite the internationally high use rates.

1. Introduction

Bike-sharing systems (BSS) have become increasingly common in urban areas around the world. The development is strongly linked to the pressing need to shift towards more sustainable urban transportation systems, expressed through increased attention to cycling in urban planning (Fishman et al., 2013; Martens, 2007; Pucher and Buehler, 2008).

It has often been suggested that BSS contribute to multiple goals in urban transportation, from decreasing emissions and congestion, to enhancing accessibility and improving the health of users. These impacts are seldom properly measured or verified, often because of the absence of appropriate data (Médard de Chardon et al., 2017; Ricci, 2015). Commonly, BSS operators claim systems are successful based on simple measures like *trips per day per bike* (TDB) (Médard de Chardon, 2019). However, TDB only reflects the distribution and coverage of the docking stations or service area and the number of bikes. It does not reveal anything about how successful the system is in servicing different groups of citizens and how equally the BSS benefits are distributed. Findings that BSSs are mostly used by certain population groups have stirred debate on the inclusiveness of BSSs (Chen et al., 2019; Dill and McNeil, 2020; Goodman and Cheshire, 2014; Hoffman, 2016; Nixon and Schwanen, 2019; Ricci, 2015; Wang and Akar, 2019). Particularly with systems that are publicly funded, it is vital to understand if, where and when the systems serve a range of groups of people.

The lack of appropriate data has been identified one of the main bottlenecks in cycling studies (Aldred et al., 2019; Aultman-Hall et al., 2012; Nello-Deakin and Harms, 2019). Collecting individual-level spatio-temporal data on a large scale has been especially challenging. The growing prevalence of BSS trip databases (origin-destination data) has improved the situation. These databases are interesting for two reasons: firstly, they often cover all trips of the system (i.e., a vast amount of data)

* Corresponding author at.: Gustaf Hällströmin katu 2 A (Physicum) PL 64, 00014 Helsingin Yliopisto, Finland.
E-mail address: elias.willberg@helsinki.fi (E. Willberg).

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and secondly, perhaps more importantly, they are generally available. However, trip data have not been used much for understanding user characteristics and usage profiles of the various user groups even though basic demographic information is commonly stored in the datasets. Clearly, there are limitations in most trip datasets such as typical scarcity of user variables and the inherent limitation of containing only realized trips. Due to open availability and automatic collection, trip data nevertheless have some clear benefits over more common data sources such as surveys used to study BSS users. Trip data can help save time and financial resources from the data collection in BSS research and planning, facilitate longitudinal research designs and reveal observed behaviour. This calls for better understanding of the potential of trip data in analysing BSS users.

Our overall aim is to understand the current state of how trip data are being used and their potential for future BSS studies. This study contributes to current scholarly discussion on BSS by demonstrating how and the extent to which trip data can be used to understand the demographics and user profiles of bike-sharing systems. First, we provide a focused literature review and quantify the use of the various BSS data sources in the recent BSS literature in order to understand which study themes trip data are commonly applied to. Second, to explore the potential of trip data, we applied it to a case study of one of the more actively used BSS in the world, Helsinki, Finland. Helsinki provides an interesting study area for user studies, as it is the capital of one of the more egalitarian countries in the world, both in terms of gender and income equality and has a very highly used BSS (World Economic Forum, 2018). From the trip records consisting all 1.5 million trips from 2017, our aim was to identify *some typical user characteristics* of BSS in Helsinki and *spatio-temporal usage profiles of user groups*. We concentrated on gender and age differences and the relationship between residential location and usage patterns. Lastly, based on the findings, we discuss the extent to which such trip data can be used to evaluate the service inclusiveness.

2. Background

Understanding urban mobility with BSSs has attracted increasing interest from scholars as the systems have become commonplace in cities. Examples include analyses of spatial patterns of trips (Levy et al., 2017; Liu and Lin, 2019), temporal rhythms (O'Brien et al., 2014; Zhou, 2015), trip frequency (Bachand-Marleau et al., 2012; Zhao et al., 2015) and trip purposes (Buck et al., 2013; Raux et al., 2017). Inclusiveness of BSSs has been been increasingly discussed in the scholarly literature. The discussion has been linked to the wider context of questions relating to transportation equity and distributive justice, which are increasingly addressed in transportation planning and literature (Cook and Butz, 2018; Litman, 2020; Pereira et al., 2017; Sheller, 2018). The inclusiveness of BSS has been debated mainly from the perspective of age, gender and ethnic differences, but also commonly in respect to wealth and home location. Bike-sharing users are disproportionately men and young adults from higher economic and educational status backgrounds (Fishman, 2015). Like cycling in general, the magnitude of these differences seems to be linked to the overall popularity of cycling in the city (for comprehensive reviews, see Fishman, 2015; Médard de Chardon, 2019; Ricci, 2015). Earlier studies suggest that in countries with high levels of cycling, the proportions of cyclists by gender and age follow the overall demographics, whereas in low-cycling countries, men and young adults tend to be overrepresented among cyclists (Aldred et al., 2015; Handy and Xing, 2011; Pucher and Buehler, 2008). Bike-sharing users are also frequently associated with being from wealthier neighbourhoods and from the central areas of cities (Ogilvie and Goodman, 2012; Raux et al., 2017; Woodcock et al., 2014). To maximise the use of the system, docking stations are often located in areas with intensive social, cultural and economic activity therefore making the docking station placement the key to explaining particular socio-economic profiles that often are disproportionately concentrated in the same areas (Ricci, 2015).

A few recent studies have used BSS trip databases to analyse how and when different user groups use the systems and this way contributed to the discussion of BSS inclusiveness. Vogel et al. (2014) found in Lyon that 65% were irregular or moderate users and that men were overrepresented among the very active users while women were more often sporadic users. In Vancouver, men, young adults, and lower-income groups were more likely to belong to 'super-users' (>20 trips/month) (Winters et al., 2019). In Chicago, women were found to make longer trips with the BSS compared to men (Zhou, 2015) while in London, a larger proportion of trips by women (22% vs 16%) were taken on weekends than men (Beecham and Wood, 2014). Young millennials (born 1995–2000) had temporal patterns of usage that differed from those of other age groups in New York, with most of their trips occurring in the middle of the day rather than during the evening peak (K. Wang et al., 2018). In relation to users' subscription types, trip records from Chicago showed that subscribers' usage patterns followed typical weekday patterns with morning and afternoon spikes and decreased usage on the weekends while non-subscribers had roughly even rental patterns between 10 a.m. and 8 p.m. and pronounced weekend usage (Zhang et al., 2016; Zhou, 2015). Finally, it has been suggested in the literature that users' home area has a role in usage patterns. In Lyon, 84% of BSS users resided within the system area, but the postal code was not strongly related to the usage patterns (Vogel et al., 2014). Users who lived in minority-concentrated and lower socioeconomic status neighbourhoods in Minneapolis-St. Paul were using the BSS more frequently and their spatio-temporal trip patterns were more diverse compared to other users (Wang and Lindsey, 2019). Travel pattern differences related to the users' home area are naturally linked more closely to the built environment, and there have been many studies correlating the use of BSS stations to the built environment characteristics (e.g. Faghih-Imani et al., 2014; Liu and Lin, 2019; Tran et al., 2015). However, these analyses are often station-centric and do not focus on how the residential area might affect individuals' usage patterns besides trip frequency.

A further look shows how BSS trip data are commonly employed in scholarly literature in quantified terms. (Table 1) (see Appendix A for review methodology). The origin-destination (OD) type BSS trip data have been the most common data type in the literature. Trip data have been used to analyse BSS in 89 studies. The second most common type has been surveys, interviews or travel diaries. Data generated by bike-sharing stations, containing either bike availability information at a given time or only the locations of the bike-sharing stations, have been the third most common data type, while other data sources have been used to a lesser extent.

The division of the study themes by studies using BSS trip data shows that BSS trip data are seldom employed to study users. Only around 18% of the studies focusing on user analyses used trip data during the review period. Most commonly, trip data have been used to analyse BSS usage where the respective proportion is 74%. Another common purpose of using trip data has been bike availability and demand prediction as well as rebalancing optimization with 64% and 36% of the studies respectively focusing on these topics and using trip data. Together with the user analyses, BSS impacts and effects or system-wide analyses have been studied with trip data to a lesser extent.

3. Materials and methods

3.1. Study area

Our study area, Helsinki, is the capital of Finland, located on the northern shore of the Baltic Sea. The city population in the beginning of 2017 was 635,000 inhabitants, but if the greater Helsinki metropolitan region is included, the total population rises to 1.45 million (City of Helsinki, 2017). The city centre of Helsinki is the largest and most important workplace hub in the region and in the country.

The aim in Helsinki is to increase the modal proportion of cycling,

Table 1
The left table shows the use of different data sources in BSS research between 1/2016–2/2018 based on search of the Scopus database (see Appendix A for review methodology). The right table shows the classification of studies using OD trip data by the study theme(s).

CLASS	DATA TYPE	NUMBER OF STUDIES
1	OD TRIP DATA	89
2	SURVEY / INTERVIEW / TRAVEL DIARY	63
3	GPS DATA	7
4	STATION LOCATION /AVAILABILITY DATA	53
5	MANUAL OBSERVATIONS	4
6	BIKE COUNTER DATA	2
7	STATISTICS	15
8	OTHER CYCLING DATA	8
9	NO CYCLING DATA	46
10	LITERATURE REVIEW	2

CLASS	STUDY CLASSIFICATION	NUMBER OF CLASSIFICATIONS	% OF ALL BSS CLASSIFICATIONS
1	**BIKE AVAILABILITY / DEMAND PREDICTION**	**25**	**64.1**
2	**REBALANCING OPTIMIZATION**	**20**	**36.4**
3	**BSS USER ANALYSIS**	**9**	**17.6**
3.1	BSS USER DEMOGRAPHICS	3	25.0
3.2	BSS USERS TRIP PURPOSE	2	100.0
3.3	BSS USER PREFERENCES / SATISFACTION	4	10.8
4	**BSS USAGE ANALYSIS**	**54**	**74.0**
4.1	TEMPORAL VARIATION	21	**80.8**
4.2	TRAVEL TIME / DISTANCE	6	**66.7**
4.3	TRAVEL ROUTES	4	**80.0**
4.4	TRIP VARIATION DETERMINANTS	12	**70.6**
4.5	BIKE AVAILABILITY	3	**50.0**
4.6	STATION PATTERNS	8	**80.0**
5	**BSS IMPACTS / EFFECTS**	**3**	**10.0**
5.1	MODAL SHARE / EMISSION REDUCTION	3	**25.0**
5.2	ACCESSIBILITY / TRAVEL TIME	0	**0.0**
5.3	USER'S HEALTH / PHYSICAL ACTIVITY	0	**0.0**
5.4	ECONOMIC	0	**0.0**
5.5	OTHER	0	**0.0**
6	**BSS SAFETY / ACCIDENTS / HELMET USE**	**1**	**14.3**
7	**SYSTEM ANALYSIS**	**10**	**13.2**
7.1	SYSTEM PRICING / BUSINESS MODEL	0	**0.0**
7.2	STATION PLACEMENT	3	**23.1**
7.3	SYSTEM PERFORMANCE EVALUATION	2	**33.3**
7.4	SYSTEM POTENTIAL	1	**5.0**
7.5	SYSTEM SUCCESS DETERMINANTS	1	**16.7**
7.6	SYSTEM ADVERTIZING	1	**33.3**
7.7	SYSTEM CONCEPTUAL DESING / PLANNING	2	**20.0**
7.8	SYSTEM BARRIERS	0	**0.0**
8	**BSS SUPPLEMENTARY SERVICES**	**1**	**6.3**
9	**OTHER BSS STUDIES**	**3**	**23.1**

from 11% in 2018 to 15% and action has been taken on many fronts to increase the role of cycling in the urban mobility mix (Helsinki City Planning Department, 2019). One of the more visible actions to promote cycling was the launch of a BSS in 2016. Governed and operated by the local transport authority (the Helsinki Region Transport - HRT), the system offers day-, week- or year-long subscription options. With the subscription, users can rent bikes for 30 min without an additional fee. In 2017, at the time of data collection, the system had 140 docking stations and 1400 bicycles in operation from May to October. In 2018, the neighbouring municipality Espoo initiated a compatible system and the bikes could be returned to either city, which also increased the number of bikes in circulation in Helsinki. In 2019, the Helsinki system expanded with 90 new stations and nearly 900 new bikes. The operating season was extended to start at the beginning of April. At the time of the data collection for this study, the stations were still located only in the central areas of Helsinki (Fig. 1).

Usage of the BSS in Helsinki has quickly expanded. Based on TDB, in relative terms, the system is one of the more popular systems in the world. The monthly mean TDB in Helsinki was 6.0 in 2017 and 8.7 in 2018. However, the system in Helsinki operates only during months that are likely to be frost-free (in operation: May–October 2017 and April–October 2018). With these figures, the BSS in Helsinki ranks close to the top in international comparisons (e.g., TDB estimate in Barcelona was 8.4, Paris was 5.2 and London was 2.0) (Médard de Chardon et al., 2017; Raninen et al., 2019). Even if assuming zero users for winter months for a more justified comparison with the year-round systems elsewhere, the yearly average TDB in Helsinki would still have been 4.4 for 2017 and 5.1 for 2018, which both rank on the higher end in international comparison. However, a recent survey suggests that system users are younger, slightly wealthier, and more educated compared to non-users, which resembles results from many other cities (Mikkonen, 2020).

3.2. Data & preparation

We used data on all the bike-sharing trips in Helsinki during the 2017 operating season (2.5.2017–31.10.2017). In the raw data set, there were 1,607,056 trip records. The system operator HRT and CityBike Finland, which maintains the BSS in Helsinki, jointly provided the data. The data were of origin-destination type (OD) and contained the basic trip information such as departure/return station, duration and distance, but also user variables such as age, gender and postal code (Table 2).

The data set had a few limitations. Firstly, the demographic variables were recorded only for the year-long subscription users. Luckily, most users subscribed for a whole year, which resulted in having demographic variables available from 35,196 of all 40,709 users (86.5%). Secondly, many users did not state their gender. Therefore, our analyses on gender were based on 23,181 users only (56.9%). Lastly, the trip records from the last day of each month were missing from the data, but because these days divided equally between weekdays, this did not skew the results.

Docking station coordinates and the locations of metro and railway stations in Helsinki were provided by HRT. For a cycling network in network analyses, we used MetropAccess-CyclingNetwork, which was based on the national Digiroad data (Finnish Transport Agency, 2017)

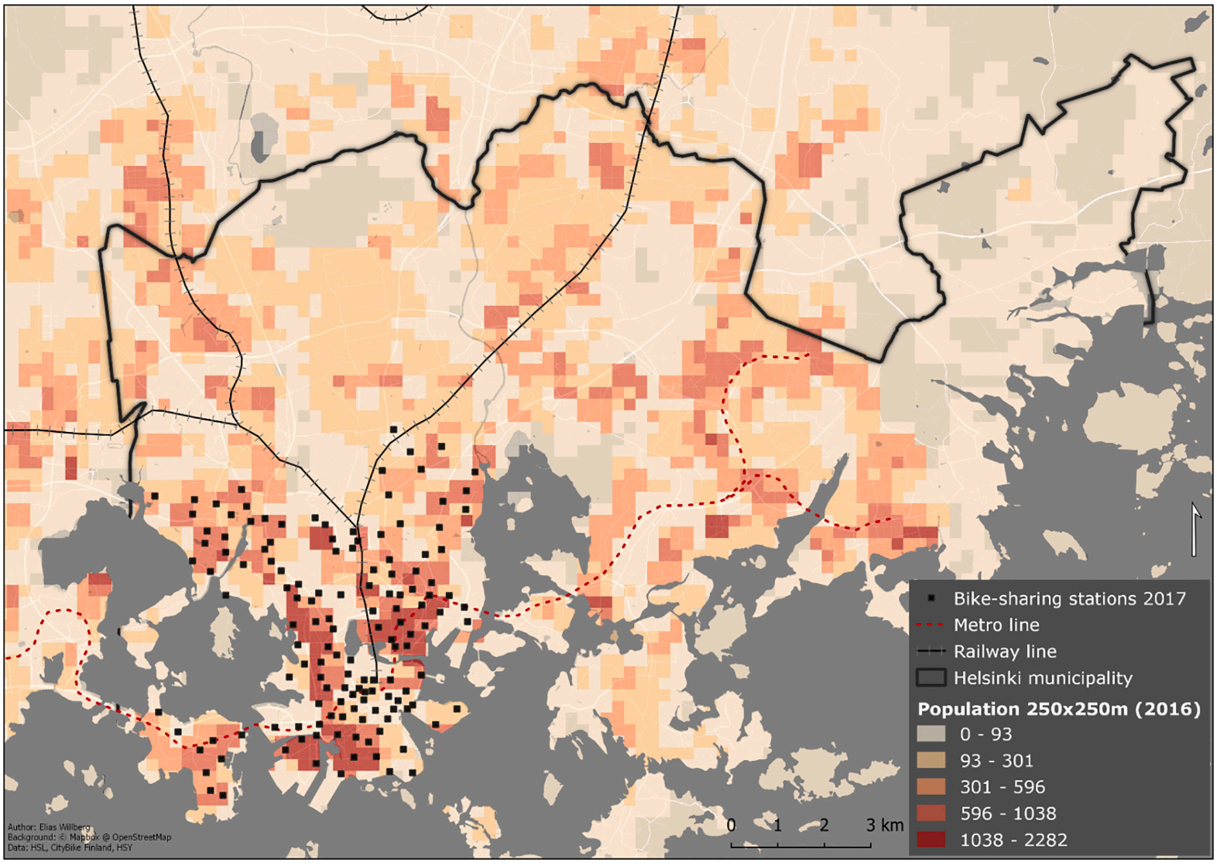

Fig. 1. The map shows the location of bike-sharing stations in 2017 with the population distribution on 250 m × 250 m grid cells.

Table 2
Descriptions of the original columns in the bike-sharing data set.

Column name	Column type	Description
Departure_time	Date	The departure time of the trip
Return_time	Date	The return time of the trip
Account	Number	User's account ID
Departure_station1	Number	The departure station ID
Departure_station2	Text	The departure station name
Return_station1	Number	The return station ID
Return_station2	Text	The return station name
Formula	Number	User's subscription type (day, week, year)
Covered_distance	Number	Trip length
Duration	Number	Trip duration
id	Number	Trip ID
uid	Number	User ID
hsl_formula	Number	User's subscription type (day, week, year)
hsl_postal_code	Number	User's home postal code
hsl_city	Text	User's home city
hsl_country	Text	User's home country
hsl_birthday	Date	User's date of birth
hsl_region	Text	User's home region
hsl_gender	Text	User's gender

and further modified by Tarnanen (2017) to suit cycling modelling in Helsinki. In demographic analyses, we used 250 m × 250 m population grid cells (Statistics Finland, 2016) and population by postal code area (Statistics Finland, 2017).

With the BSS trip data, we performed data pre-processing and analysis with Python (the Python code available on GitHub: https://github.com/EWillberg/Bike-sharing). First, we pre-processed the bike-sharing trip data set. We derived multiple new variables from the trip data set based on existing variables, such as the user's age from the date of birth, the trip speed from the trip duration, and the distance and the trips per day from the total trip count and the season length (see Appendix B for a full detailed list of derived columns and their explanations). Next, we removed records with an unlikely or extreme trip speed, duration or distance, trips that had been taken by the users without a proper subscription and trips departing from or returning to stations that were not in public use or were outside Helsinki (see the Appendix C for a detailed list of trip filter criteria). We also enriched the data with ancillary data sets. Using the population layer, we compared the bike-sharing users against the whole population of Helsinki while the locations of the bike-sharing stations allowed us to examine the spatial variation of trips. We also used network analysis to determine the shortest paths for all the possible station pairs (n = 19,460) with the Closest Facility tool of ArcMap 10.3. The shortest paths were compared to the realized trip distances along the trip pairs. We also identified the bike-sharing stations within 100 m of the nearest public transport hub to flag all the trips that had either departed from or returned to these stations as potential public transport chain trips.

3.3. User classification

We classified the users according to five criteria and analysed the resulting classes spatio-temporally. The criteria were age, gender, home area, subscription type and use activity. We divided users by gender into two classes (female/male) excluding cases in which gender was not reported. With the age criterion, we divided the users into cohorts of 15–29, 30–44, 45–59 and 60–74. (Users under 15 or over 75-year-olds made very few trips; hence, we left them out). With the home area, we used a binary classification: home within BSS area (users whose postal code area had at least one bike station) vs. home outside BSS area (no bike station in the postal code area). The subscription type classification had three classes, which were the available subscription options for users – day, week and year. Lastly, we focused on the use activity and divided the users into quintiles based on their total trip count but also used the trip counts as continuous variables in the statistical tests. The analyses of use activity were based on data from all subscription types.

3.4. Statistical tests

To validate differences in usage patterns between user groups we tested them statistically with each user-related variable in our data set. For binary classifications (gender and home area), we compared groups with Student's *t*-test statistics. For user groups with multiple populations (age groups, subscription type, use activity), we used the ANOVA technique with Tukey's pairwise post-hoc tests. As the precondition for ANOVA, the homogeneity of variance assumption was tested and met with each of these three user-related variables. For this reason, Tukey's post-hoc tests were selected to analyse the variation within the variables. While ANOVA provided information about overall differences with each user-related variable, Tukey's test determined which groups within each variable statistically significantly differed from each other. The full resulting tables from the t-test and ANOVA statistics for the user-related variables are presented in appendices D—H.

4. Results

4.1. The use of the bike-sharing system in Helsinki

In the Helsinki trip data set, 1.5 million BSS trips were made by 41,700 users in 2017. On average, 6.0 TDB were made during the entire season from May to October. The summer months from June to August were the busiest with TDB close to 8.0 while October had the least number of trips with only around 3 TDB. There was also weekly variation in trips. A median trip was 1860 m (mean 2204 m) long and lasted 10.5 min, which is shorter than the average distance of 3300 m for all cycling trips in Finland (Liikennevirasto, 2018). The median speed of the trips was 11.9 km/h, which accounts for 30 s at the start and 10 s the end of the trip for taking out and returning the bike, as measured by Jäppinen et al. (2013). The great majority (96.7%) of trips took less than the 30-min limit after which there would be an additional cost.

4.2. User characteristics

Fig. 2 presents the available demographics of BSS users in Helsinki. The comparison of bike-sharing user and trip demographics against the population demographics in Helsinki shows that young adults are overrepresented while older age groups are underrepresented. Trip-level inspection shows the gender differences especially in the age groups from 20 to 44. In this age group, men are using the system clearly more than women. Spatial inspection shows that users living within the system coverage area (69% of all users) made 79% of the trips despite this group accounting for only 40% of the city population. Most users (82%) are yearly subscribers, and they made 92% of all trips, which suggests that the system users are largely locals.

4.3. Temporal usage profiles

Fig. 3 shows the temporal variation in BSS use among the different user groups. Age group and subscription type demonstrate the highest temporal variations. For example, during weekdays, the 40–59 age group had peaks in the morning and afternoon, suggesting that their trips have a strong commuting function. The youngest age group 15–29-year-olds make relatively more trips in the evening, which may be related to their trips having a stronger leisure time function or to more fragmented commuting hours. In respect to the use activity

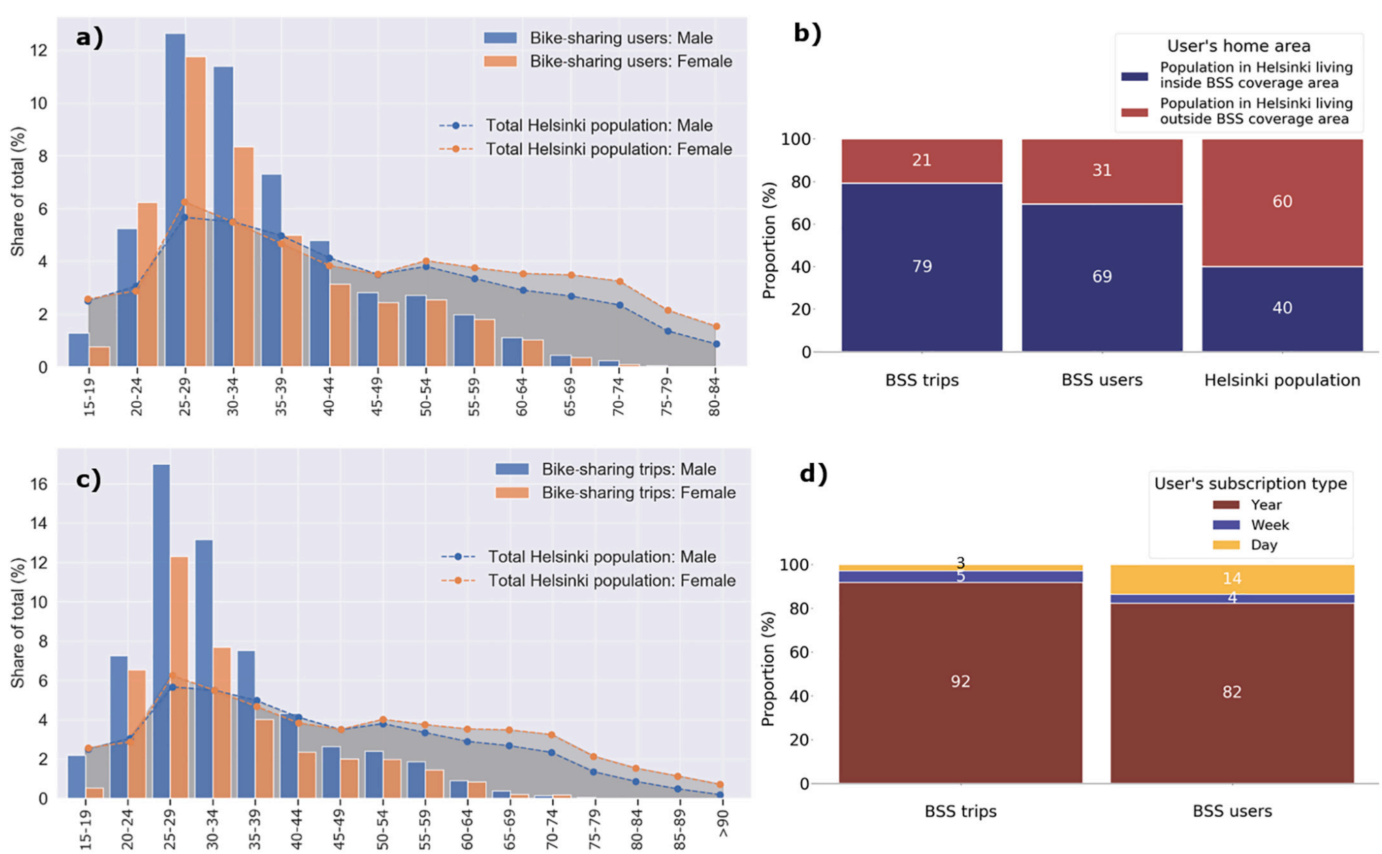

Fig. 2. Charts a) and c) show the share of users (a) and trips (c) by age group and gender compared to the demographic structure of Helsinki. Chart b) shows the share of users, trips and Helsinki population by home area. Chart d) shows the share of users and trips by the user's subscription type.

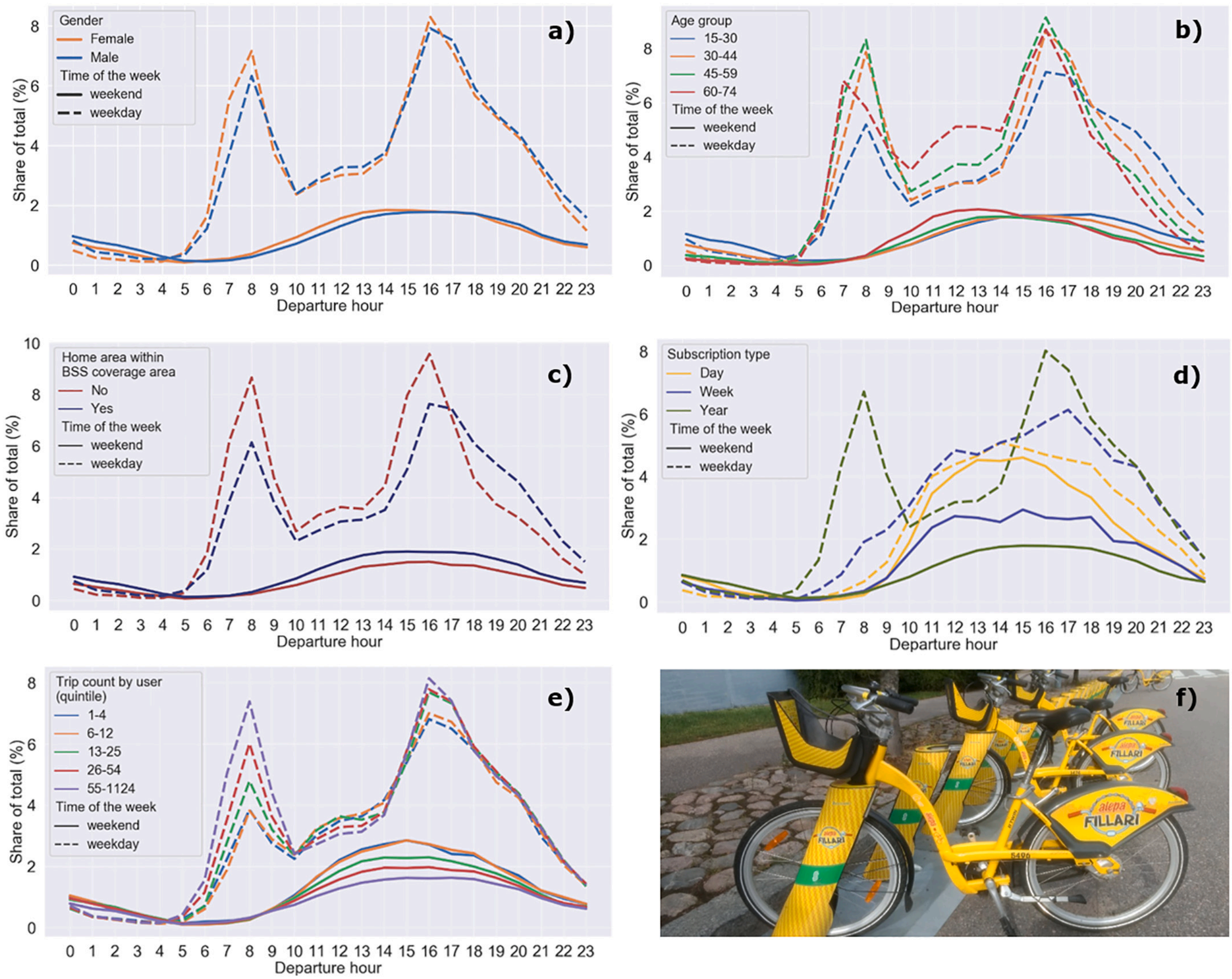

Fig. 3. Charts show the hourly differences in trips by user groups for gender (a), age group (b), home area (c), subscription type (d) and use activity (e) classification both on weekdays and weekends. Figure f) shows a bike and docking station of the Helsinki BSS (photo by the first author).

classification, more active users have relatively more trips on weekday mornings and afternoons compared to less-active users who respectively have a higher proportion of trips during weekends, which suggests that active users are hiring bikes often for commuting purposes. Similarly, users residing outside the system coverage area have higher peaks in the morning and afternoon on weekdays. We also found evidence that users

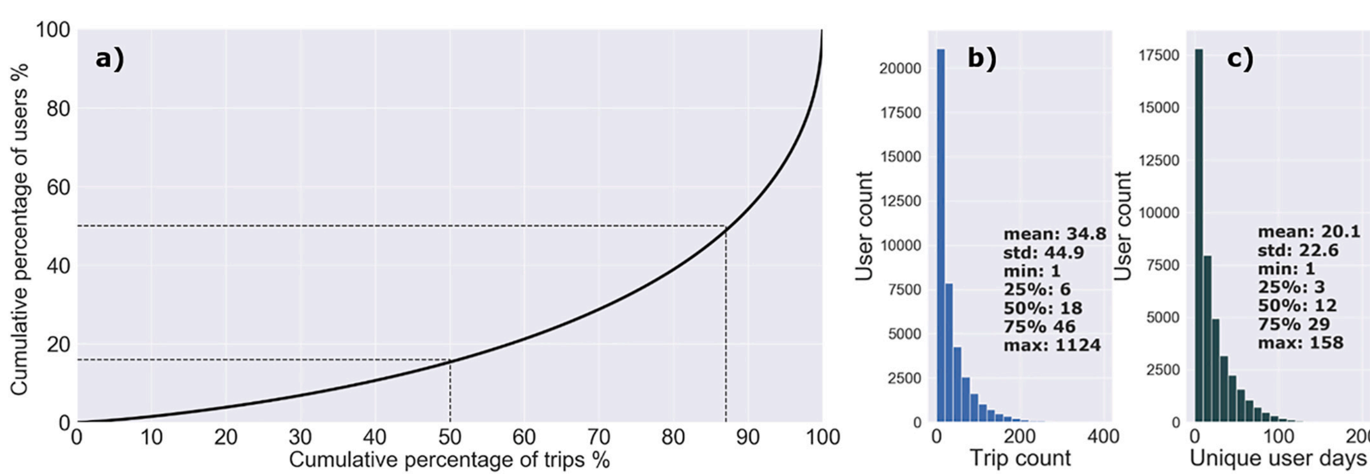

Fig. 4. Chart a) shows the cumulative use of the Helsinki BSS. Charts b) and c) show user distribution by trip count (b) and unique user days (c).

residing outside the coverage area have a clearly higher proportion of departures near public transport hubs on weekday mornings and respectively returns on weekday afternoons, which indicates their higher integration with other public transport on commuting trips (Appendix I). Users with a day subscription have similar temporal trip share both on weekdays and at weekends while users possessing an annual subscription have very different trip patterns on the weekdays compared to the weekends. Lastly, there are no clear gender differences between the temporal patterns of bike trips.

4.4. Usage activity and patterns

Half of BSS trips, 50%, are taken by only 16% of the users (Fig. 4) (Cf. 50% of the trips by 5–6% of the users in Denver, London and Vancouver in Médard de Chardon (2019) and Winters et al. (2019)). This means that most of the users do not use the system frequently. During the 177-day season, a median user hired a bike on only 12 days and made 18 trips. User demographics of the more active groups are more skewed compared to all users (Table 3). The proportion of younger, male and those living within the station network is pronounced. There is also variation in usage patterns between trip count quintiles. The users with the most trips (Q5) rode slightly faster and took shorter trips, and they make relatively more trips on weekdays and rode more often along the shortest route. In this respect, the behaviour of active users resembles two of the four types of cyclists "strong and fearless" and "enthused and confident" that are associated with higher confidence, as discussed by Dill and McNeil (2013). The results suggest that the higher the number of trips per user, the more these trips are taken from a certain station at a certain time. However, these results are also due to the natural tendency of higher standard deviations given more trips. The trips are also likely to be chained more often i.e., a user's next trip departs from the same station at which the previous trip ended. Also, the last return of their daily trips is more frequently to the same station at which the user did their first hire of the day. These variables all indicate that active users may have more habitual trip patterns compared to less-active users. It is likely that the BSS is an important part of many active users' daily mobility habits, especially on commuting trips, whereas less-active users take bikes for more casual and spontaneous trips.

5. Discussion & conclusion

Understanding how BSSs serve different user groups and needs is important in developing them and directing promotional actions for potential new users. Our results from the Helsinki BSS help exploration of the value of BSS trip data in understanding user characteristics and profiles.

Our results from the Helsinki BSS point to challenges in system inclusiveness, despite high TDB. We observed similar user profiles than in the earlier literature with pronounced high proportions of especially young adults but also, to some degree, of men (Fishman, 2015). The bike-sharing users in Helsinki are a less diverse group of people than cyclists in general in the city (Helsinki City Planning Department, 2019), which is contrary to what Buck et al. (2013) found in Washington, where BSS users were more diverse. Most trips (79%) are taken by those residing within the system area, but the population of this area accounts only for 40% of the city population, which further points to the importance of station proximity and placement (Ogilvie and Goodman, 2012; Raux et al., 2017; Vogel et al., 2014). Increasing the BSS coverage area may therefore improve the system's inclusivity as shown by Goodman and Cheshire (2014), but without sufficient travel demand, they may also reduce the system's performance at least when measured with TDB, and not be cost-effective (Médard de Chardon et al., 2017). Public participation processes may mitigate this challenge by helping to understand the local context. For the recent expansion in Helsinki, citizens were consulted on their preferences for station placement through an online map-based survey and the results were used in the expansion design, which is a positive step towards better inclusiveness and will help the system managers to direct new stations to areas with the most need.

Our results also showed that most trips are generated by a minority of users, which points in the same direction with recent findings from Vancouver, Denver and London, although less strongly (Médard de Chardon, 2019; Winters et al., 2019). This difference may be linked to high overall levels of cycling in Helsinki, which may indicate broader participation of various groups with varying cycling capabilities. High BSS use in Helsinki is nevertheless largely generated by a limited group of people, who are disproportionately younger adults (Q5 had lowest median age, 30) and male (Q5 had the highest proportion, 62%). For this group, commuting is likely to be a major part of their BSS use, which adds to the findings on BSS 'super-users' by Winters et al. (2019). The most active user quintile in our study had distinctive temporal and spatial patterns, implying habitual use. The proportion of users residing within the BSS area were furthermore the largest within the most active user quintile. To summarize, the results from Helsinki demonstrate that high TDB can hide patterns in which most use is contributed to by a limited proportion of users whose home location and typical mobility patterns probably align well with the system network.

We demonstrate the options for using BSS trip data in analysing BSS users and usage. This is important as BSS trip databases are increasingly available, which is not typical of many other cycling data sources.

Table 3
Variation of user variables by user quintiles based on trip count.

Classification (user quintile based on trip count)	User ID count	Gender share (female/male)	Median user age	Home area share (users within the system network area) (%)	Median trip duration (s)	Median trip distance (m)	Median trip speed (km/h)	Median week / weekend use ratio
User quintile Q1 (1–4 trips)	9209	48/52	35	52	1031	2499	9.0	0.60
User quintile Q2 (5–12)	7812	49/51	33	64	790	2053	9.9	1.20
User quintile Q3 (13–25)	7548	48/52	32	73	687	1901	10.5	1.20
User quintile Q4 (26–54)	8008	45/55	31	77	635	1840	10.9	1.24
User quintile Q5 (55–1124)	8132	38/62	30	82	592	1823	11.4	1.46

Median distance difference (realized route - shortest route) (m)	Potential PT trip percentage (departure/return station in the immediate vicinity of PT hub) (%)	Standard deviation of departures per station	Standard deviation of departures per hour	Next departure from earlier return station percentage (%)	Percentage of days where the first departure station is the last return station (%)
285	25.0	0.0	0.0	0.0	0.0
124	33.3	0.9	0.8	16.6	10.0
78	35.7	1.9	1.3	19.2	12.5
53	36.3	3.4	2.2	20.5	14.7
39	36.4	7.4	4.9	24.8	20.0

Helsinki and many other cities including London and New York have shared BSS data openly, a strategy that generates new research (Willberg, 2019). Based on our results, trip databases are well established to support spatio-temporal analyses on where and when trips are being taken in general and how the demand varies at the stations. However, we show that trip data are not used much for BSS user analyses. Even trip data containing only basic user-specific variables can uncover differences in overall use and in spatio-temporal travel patterns between different groups. This information can help urban planners and system managers in developing BSSs, understanding which trip types their bikes are typically used for as well as capturing shortcomings in their inclusiveness. It also calls for further research attention to trip data in studies with a focus on users.

Obviously, a more complete picture on situational, spatial, social and economic aspects of bike sharing users often requires the use of more qualitative data sources or the integration of multiple sources. The limitations of our study highlight this need. Firstly, a significant proportion of users did not provide gender information and an unbiased distribution was assumed for this group, which needs to be considered in respect to our results on gender. The lack of data is likely to reflect the user registration form design, but also potentially the diversity of gender identities adding a challenge to understanding BSS gender patterns results. Secondly, we had only a little data on the young (under 15 years) and the elderly (over 75 years) users, which in the case of the former group is partly due to the BSS registration requiring an online bank account and in the case of both groups, potentially partly due to the challenges of using the heavy bikes in the Helsinki BSS. Understanding the travel needs and use barriers of those groups who are underrepresented in BSS use is nevertheless crucial for improving inclusivity (Dill and McNeil, 2020; Nixon and Schwanen, 2019; Ricci, 2015). Thirdly, no data were available for us to analyse users' economic or social background and their potential effects on BSS usage patterns. Additional socio-economic variables in trip datasets, such as education, economic background and ethnicity would help to deepen understanding on the inclusiveness of BSSs beyond age, gender and home location. However, collection and linking of such sensitive personal data might be questionable from the system operators' and users' point of view. Increased co-development of solutions to data collection and secure sharing could benefit both researchers and BSS managers in this respect. Nevertheless, trip data can also help us to understand the limitations of other sources. For example, our results with trip data captured the difference between the gender shares of users and the gender shares of realized trips assuming an unbiased distribution of those not reporting their gender in our data. This result that was not captured by the user survey. In many cases, different BSS data sources can and should complement each other. Lastly, trip data enables analysing inherently anonymized individual-level cycling data as docked stations rarely represent the true origin or destination of the trip. Therefore, it can help to uncover nuanced cycling patterns or even general mobility flows in urban areas without compromising user's privacy.

Author statement

The authors have collaborated on all sections of this paper, contributed to the development of the overall argument and agreed the final version.

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Supplementary data

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